

Surgical Treatment of Angina Pectoris

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SINCE Heberden's classic description¹ of the syndrome of angina pectoris in 1768, considerable effort by medical investigators has been directed toward this problem. Although these studies have enriched the literature and have added to greater knowledge and better understanding of the various aspects of coronary artery disease, the surgical approach to the condition has remained inconclusive and controversial. A number of factors probably account for this disputed and uncertain status of the surgical treatment of coronary artery disease. Among these, perhaps the most important is the fact that the natural course of the disease is often so highly variable, not only among different patients but even in the same patient at different periods, and may be greatly influenced by many factors, both intrinsic and extrinsic, as well as by medical therapy. It has long been recognized, for example, that significant coronary artery disease could be present at necropsy with little disturbance of cardiac activity during life. On the other hand, Sir William Osler² made the observation more than fifty years ago that in some fatal cases of angina pectoris there was little alteration in the heart or coronary arteries. Because of these and other variables and the consequent inability to provide a properly controlled study, precise and accurate evaluation of the clinical results of surgical therapy has been extremely difficult.

The basic pathologic lesion in coronary artery disease is atherosclerosis, which leads ultimately to narrowing or occlusion of the

lumen by progressive intimal thickening, intimal ulceration, hemorrhage, or superimposed thrombosis. As a result of this occlusive process, the myocardial circulation is reduced to a variable degree, depending upon the nature and extent of the lesion and the degree to which intercoronary collateral vessel development takes place. Serious disturbances occur when the latter compensatory mechanism fails to meet the ischemic changes produced by the atherosclerotic process. One or more of the following effects may then take place: angina pectoris, myocardial infarction, or mechanism failure. Myocardial damage leads to fibrosis, congestive failure, aneurysm formation, ventricular septal defects, or external rupture.³ These disturbances ultimately lead to variable degrees of disability, invalidism, and death.

Accordingly, surgical treatment of coronary artery disease has been directed toward relief of these adverse effects of coronary arterial insufficiency. A number of different methods and procedures have been proposed and applied for this purpose, but in general they may be classified as follows: (1) denervation of the heart for the relief of angina pectoris; (2) decreasing metabolic demands on coronary circulation by thyroidectomy; and (3) improvement of arterial circulation to the myocardium.

More than fifty years have elapsed since the first surgical attack was made on angina pectoris. This consisted in interruption of cardiosensory and motor pathways to the heart by sympathectomy, a procedure which was originally suggested by Francois-Frank⁴ in 1899, and successfully performed by Jonnesco,⁵ in 1916. While many experimental and clinical investigations have since provided a better understanding of the underlying anatomic and physiologic principles of this method of attack, its clinical value remains uncertain. Anatomic and physiologic studies have demonstrated that the sensory nerve

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endings of the heart and aorta are present in the myocardium, endocardium, and epicardium, and in the adventitia of the coronary arteries. The neurons to these sensory endings converge in the periarterial plexus of the coronary arteries, traverse the superficial and deep cardiac plexuses, and course in the middle and inferior cardiac nerves, which join the corresponding cervical ganglia of the sympathetic chain. Practically all of these outbound fibers then descend to the upper thoracic ganglia and finally reach their cells in the spinal ganglia by passing through the white rami communicantes into the central portions of the first thoracic and upper four or five intercostal nerves. The vasomotor efferent or accelerator impulses to the heart and coronary arteries differ from the sensory, and their actions and pathways are not so well understood. These pathways involve both vagal and sympathetic nerves, but the exact mechanism of their action in producing vasoconstriction and vasodilatation has been difficult to determine precisely.

Three general methods have been employed clinically to denervate the heart: (1) cervicothoracic ganglionectomy; (2) posterior rhizotomy; and (3) paravertebral chemical (alcohol) block of the upper four or five sympathetic ganglia. A more accurate and lasting effect is obtained by the first two procedures; they require a major operation, however, and are associated with an operative mortality of about 8 to 10 per cent.⁶ Good results in terms of relief of pain, increase in work capacity, and improvement of general condition have been reported in 70 to 75 per cent of cases following all these methods, but there is no good evidence that survival expectancy is increased. It should be recalled that destruction of cardiosensory nerves and the protective alarm mechanism occurs concomitantly.

The procedure of total thyroidectomy to decrease the metabolic demands of the body for the treatment of coronary insufficiency is now only of historical interest.⁷ It is of interest to observe that in 1937 Parsons and Purks,⁸ following a collection of tabulated data from various sources, found that in a

series of 133 cases in which thyroidectomy was performed for angina pectoris excellent results were obtained in 55 per cent and that 28 per cent were moderately improved. The operative mortality was almost 4 per cent. Hypothyroidism may be induced more easily and safely by the administration of radioactive iodine.⁹ Good results in relief of severe angina pectoris have been reported in about 75 per cent of cases.^{10, 11} Final evaluation of this therapeutic approach in terms of work capacity and longevity remains to be determined.

Direct and indirect surgical methods designed to improve the arterial circulation of the myocardium have been developed following a better understanding of the factors underlying myocardial ischemia. Certain physiologic principles and pathologic changes concerning coronary arteries are of considerable surgical importance. Functionally the coronary arteries are largely "end arteries." Although intercoronary communication may exist, collateral circulation from this source is usually not sufficient to maintain viability of the myocardium following sudden occlusion of a major branch of a coronary artery. In a slowly developing occlusive lesion, progressive increase in intercoronary collateral channels may take place and provide some protection to the ischemic segment of myocardium. Although arteriosclerotic change may be generalized, it commonly is segmental. Atheromata may occur anywhere in the coronary arterial tree, but points of vessel bifurcation are sites of predilection. Frequently the occluding lesion is segmental in nature, is less than 5 mm. in length, and often lies in the proximal larger arteries.^{12, 13} Distally, a thrombus may or may not be present.

On the basis of these observations, investigators have been encouraged to develop surgical procedures designed to augment arterial bloodflow to the myocardium through increase in intercoronary collateral circulation or by restoring circulation in the involved coronary artery. These various surgical methods may thus be classified into two broad categories,

namely, indirect and direct approaches.

Among the former, a number of different procedures have been devised and employed both experimentally and clinically to increase coronary collateral circulation. These vary in complexity from the simple placement of an irritant such as talc or asbestos in the pericardium¹⁴ or ligation of the internal mammary arteries¹⁵⁻¹⁷ to the grafting of various vascular structures such as the pericardium,¹⁸ omentum,¹⁹ pectoral muscles,²⁰ lung,^{5, 21, 22} and intestines²³ to the myocardium; the implantation of a systemic artery such as the internal mammary artery into a tunnel in the myocardium;²⁴ and arterialization of the coronary sinus.²⁵ Perhaps the most popular of these procedures is the Beck I operation, or some modification of it, consisting in abrasion of the epicardium by mechanical or chemical (phenol) means, partial ligation of the coronary sinus, the use of asbestos or talc poudrage, and mediastinopexy. In a series of 347 patients in which this type of procedure was employed during a period of approximately 4 years, Beck²⁶ reported an operative mortality of 6 per cent and a total mortality after discharge from the hospital of 9.2 per cent. Of the 295 patients who were still living at the end of this period, 32 per cent were classified as having an excellent result and 62 per cent a good result. Using a somewhat similar procedure on 57 patients, Thompson and Plachta²⁷ reported an operative mortality of 12 per cent with results classified as 90 per cent improved in 50 per cent of the cases and 75 per cent improved in 40 per cent of the cases. Advocates of this procedure have been able to demonstrate that it provides an increase in the survival rate of dogs following ligation of the anterior descending coronary artery and have contended that this is due to increase in intercoronary anastomoses. On the other hand Gage and his associates,²⁸ using an experimental procedure that produced gradual occlusion of the circumflex and anterior descending branches of the left coronary artery, were unable to demonstrate any beneficial effects of poudrage in terms of a de-

crease or delay in mortality or a reduction in incidence of gross infarction.

Particularly important in this connection and in the critical evaluation of these indirect revascularization procedures as emphasized by these authors as well as by Gregg and Sabiston²⁹ is the concept of whether or not they can produce an increase in collateral circulation above that produced by the disease itself.

Second to the Beck I operation in clinical popularity has been the bilateral ligation of the internal mammary arteries, frequently combined with poudrage or retrosternal neurolysis. This procedure was first suggested by Fieschi in Italy in 1939¹⁵ and employed in a number of patients with coronary insufficiency by De Marchi, Battezzati, and Tagliaferro.¹⁶ The pericardiophrenic arteries arising from the internal mammary arteries supply a significant quantity of blood to the pericardium and give origin to small vessels to the posterior wall of the left atrium. In necropsy preparations vascular communications are demonstrable between the internal mammary artery and the coronary circulation. In this country Glover and his associates^{17, 30} employed this technic in the treatment of coronary arterial disease, reporting relief of angina in 68 per cent of patients with an operative mortality of 7 per cent. The simplicity of the procedure, the variable course of the disease, and the relatively low associated operative mortality undoubtedly account for the widespread acceptance of this procedure prior to adequate clinical or experimental evidence that this operation significantly altered myocardial blood flow. Sabiston and Blalock³¹ and numerous other investigators in experimental studies have demonstrated no evidence of value in internal mammary ligation. Even under special laboratory conditions permitting an increase in flow in the ligated mammary arteries, no significant increase in retrograde coronary flow nor protection of the heart against coronary arterial occlusion could be demonstrated. The clinical results following sham operations, i.e., transection of the

sternum without mammary ligation, are as good as those receiving the ligation.³²

In 1946 Vineberg³³ first proposed, and later he and other investigators demonstrated, that if a systemic artery such as the carotid, subclavian, or internal mammary artery were implanted in a myocardial tunnel, the artery would eventually form anastomoses with the terminal branches of the coronary arteries. These arteriolar communications tend to occlude by intimal and medial thickening in the normal heart; these obliterative changes, however, do not take place in an ischemic ventricle. Although these vascular channels remain patent and undoubtedly conduct some blood, flow studies have shown this magnitude of flow to be disappointingly small.^{34, 35} Vineberg³⁶ in 1958 reported the results of this procedure in 59 patients. In 17 patients with angina pectoris at rest the operative mortality was 59 per cent. In 40 patients with less severe symptoms the operative mortality was 5 per cent, with 78 per cent markedly improved after surgery. The unpredictable augmentation of myocardial blood flow combined with the technical problems associated with a successful operation has prevented wide acceptance of this procedure for the present.

It should be noted that, experimentally, arterialization of the coronary sinus (the Beck II operation) affords the most effective protection against ventricular fibrillation following acute coronary occlusion.²⁶ The anastomosis of a systemic artery to the coronary sinus is, however, fraught with many technical difficulties, requires a second procedure to ligate the coronary sinus partially, and clinically has had an operative mortality of 15 to 20 per cent. The resulting beneficial hemodynamic changes are usually lost within 6 months after operation.

Numerous investigators have attempted to graft richly vascularized tissues upon the surface of the heart. At present it has been difficult to demonstrate conclusively a significant flow of blood from the graft to the heart wall. Each worker has stressed the importance of the epicardial barrier to these revasculari-

zation procedures. Removal of the epicardium by mechanical or chemical means allows for better surface revascularization.³⁷ There is no strong evidence that any of these vascular pedicles significantly improves the myocardial circulation. Attempts to revascularize the myocardium from within the ventricular chamber by means of small plastic T tubes implanted within the wall of the ventricle have not justified clinical application.^{38, 39}

More recently, still another procedure has been introduced by Day and Lillehei,⁴⁰ consisting in the creation of a right-to-left shunt by anastomosis between the pulmonary artery and left atrium to lower arterial oxygen saturation and thus utilize the stimulation of hypoxia in the development of intercoronary anastomosis. Experimentally they were able to demonstrate a significant increase in intercoronary anastomosis within 1 month after operation and reported dramatic improvement in one patient in which this procedure was used.

The direct surgical approach is aimed at increasing arterial inflow through the coronary arteries by removal of the occlusive lesion or by anastomosis of a systemic artery to the coronary arteries distal to the occlusion. This approach is based upon the demonstration that patients with angina pectoris not infrequently have partial or complete occlusion of a major coronary artery in the proximal portions of the vessel, which is segmental in character with a relatively normal distal arterial bed.¹² In light of this evidence and the fact that effective methods have been developed for the treatment of similar segmental occlusive lesions in peripheral vascular disease, it was only natural to consider application of these procedures, such as resection and graft replacement, endarterectomy, the bypass graft, and the patch graft to segmental coronary occlusive disease. The feasibility of utilizing these procedures has been well demonstrated by an increasing number of investigators in clinical studies as well as in experimental animals.⁴¹⁻⁵³ In the clinical application of these procedures particular interest has been devoted to endarter-



Figure 1

Photograph showing bypass Dacron graft between aorta and left circumflex coronary artery in dog that maintained coronary flow satisfactorily following ligation of left main coronary artery.

ectomy following the original report of Bailey and associates⁵⁴ on its successful employment in 2 patients. More recently Kattus and his associates^{55, 56} have reported their observations on a series of 11 patients suffering from incapacitating angina pectoris in which coronary endarterectomy was performed. Among the 5 patients surviving operation, results were considered excellent in 2, good in 1, and fair in 2.

Efforts to utilize the bypass graft principle by some form of systemic-to-coronary artery anastomosis have been predominantly, if not completely, experimental in nature. Some of the earliest attempts of this kind were reported by Murray and his associates,⁵⁰ who utilized the carotid artery as a free graft from the aorta to the left anterior descending coronary artery. Among 17 dogs in which this procedure was performed, 5 survived 2½ hours to 8 days without infarction. A higher rate of successful results was more recently reported by Thal and associates,⁵³ who anastomosed the left internal mammary artery to the left circumflex coronary artery over a glass cannula to permit blood flow during the anastomosis. Fifty per cent of the animals

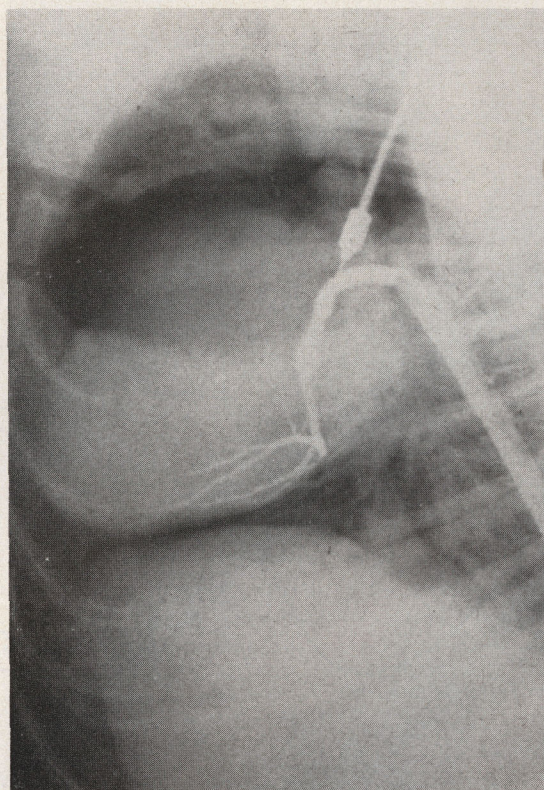


Figure 2

Coronary arteriogram made 24 hours after installation of bypass graft between aorta and left circumflex coronary artery demonstrating patency of anastomosis and filling of distal branches of circumflex artery.

survived the operation and the anastomoses were found to be patent 2 to 6 months later in 41 per cent. Somewhat similar results have been obtained in our laboratory with use of a knitted Dacron graft 3 to 5 mm. in diameter attached proximally by end-to-side anastomosis to the ascending aorta and distally by a similar anastomosis to the left circumflex coronary artery or the left anterior descending coronary artery with the use of a temporary internal shunt (figs. 1-3). Following completion of the anastomoses, the left main coronary artery is ligated, leaving the left ventricle dependent on the graft for its blood supply. These grafts have functioned in about 50 per cent of the cases.

Another procedure that has been studied experimentally in our laboratory is concerned

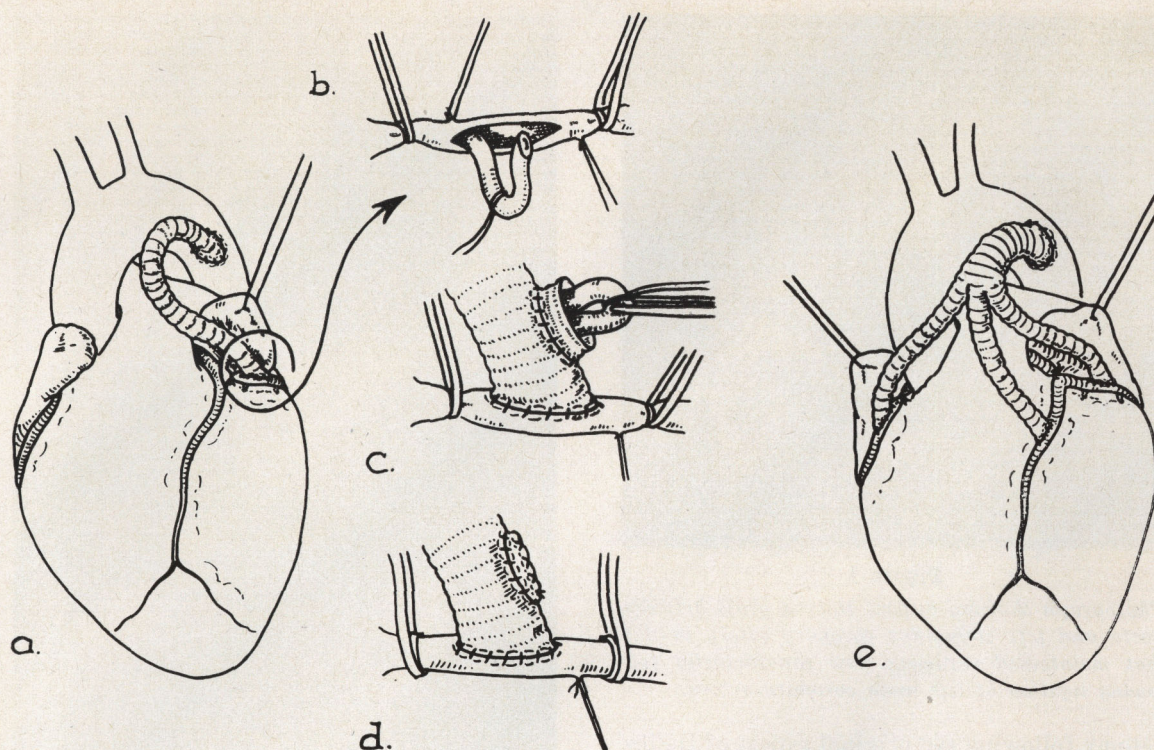


Figure 3

Diagrams depicting (a) aorta-to-coronary artery bypass graft showing relationship to heart and aorta; (b-d) technic of insertion of internal polyethylene shunt and its withdrawal upon completion of anastomosis and (e) maintenance of entire coronary circulation by means of a trifurcated bypass graft.

with the use of the patch graft.⁵⁷ We have used this procedure extensively in the surgical treatment of other forms of well-localized atherosclerotic occlusive disease with or without endarterectomy, and it has been found particularly valuable in lesions involving smaller arteries such as the internal carotid, vertebral, and popliteal arteries. These small patches of autogenous or synthetic graft material provide replacement of a sufficient part of the circumference of the artery to permit restoration of a normal lumen following arteriotomy. Successful application of this procedure to the coronary artery of dogs has been demonstrated in our laboratory (figs. 4-6). On this basis and from our clinical experience with its use in other small arteries, the patch graft would seem to have some advantages in the treatment of certain forms of well-localized coronary artery occlusive lesions.

It is thus apparent that a wide variety of surgical procedures has been devised and advocated for the purpose of improving myocardial circulation. Extensive investigations have also been done to evaluate the results of these procedures. In general the experimental design of most of these studies has employed one or more of the following criteria of benefit: (1) reduction in the amount of myocardial damage or in mortality rate in the group of animals having the experimental "protective" operation as compared with the controls following occlusion of a test artery, such as ligation of the left anterior descending coronary artery; (2) increase in retrograde coronary backflow in the experimentally treated animals as compared with the controls; and (3) morphologic evidence of new vessel formation following the experimental procedure. Evaluation of results of clinical application of these various proce-



Figure 4

Photographs illustrating (a) arteriotomy of left circumflex coronary artery with internal polyethylene shunt in place.

dures has been based largely upon such criteria as survival rate, symptomatic improvement, and increased work or exercise capacity, with the patient serving as his own control. A wide range of operative mortality has been reported for these various surgical approaches from less than 5 per cent for the simpler procedures to over 50 per cent for the more extensive operations.

Efforts to assess the relative value of these various methods of surgical treatment of coronary insufficiency are fraught with many difficulties. As indicated previously, these are due in large measure to the highly variable course of the disease and to lack of precise and accurate criteria of benefit. Particularly striking is the remarkable similarity in the clinical results following these widely varying methods as reported by their respective advocates. This would suggest that they all possess some common factor or mechanism other than improvement in coronary circulation. This is well exemplified by the subsequent demonstration in well-controlled studies that certain procedures, such as ligation of the internal mammary artery, do not in-

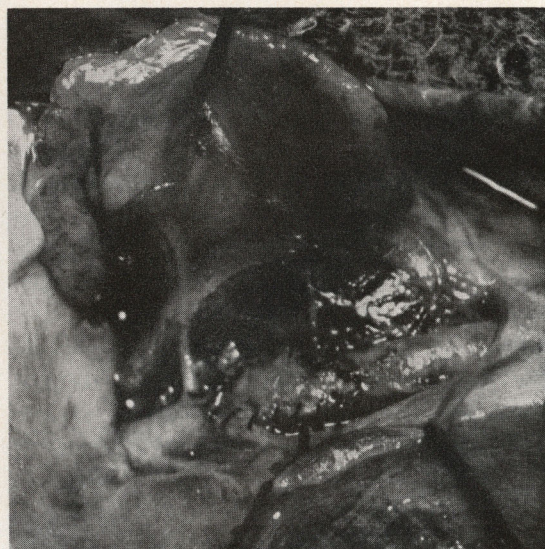


Figure 5

Appearance of vessel (fig. 4) after closure of artery with use of Dacron patch graft to avoid constriction of lumen.

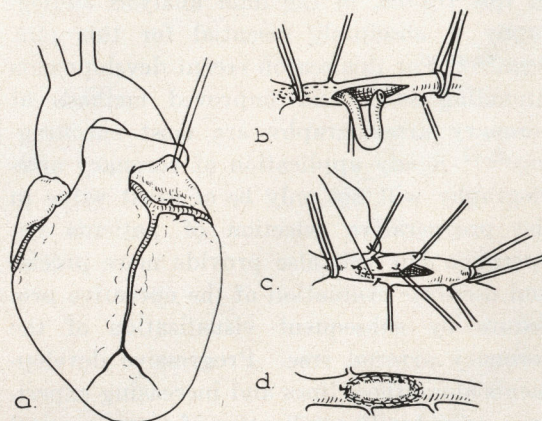


Figure 6

Diagrams (a-d) depicting technical aspects of arterial repair of circumflex coronary artery with aid of internal shunt and small Dacron patch graft.

crease circulation.⁵⁸ Obviously the major difficulty in the critical evaluation of these methods of surgical treatment clinically lies in the lack of precise and accurate methods of demonstrating increased myocardial flow.^{59, 60}

Despite these considerations there are reasons to believe that the surgical approach to this problem offers some promise.⁶¹ Certainly for the relief of intractable pain uncontrolled by medical means, surgical methods by one of the simpler procedures, such as neurectomy

or chemical or mechanical de-epicardialization, may be employed with a low operative risk and high incidence of relief of pain. The most meaningful surgical approach to this problem, however, would seem to lie in those procedures designed to restore normal blood flow in the obstructed segment of the coronary arterial tree by methods, such as endarterectomy, bypass graft, or patch graft, that have proved so effective elsewhere. Better general acceptance and more widespread clinical application of these methods, however, await further developments along certain lines including particularly proper selection of patients for this purpose, diminution in the risk of operation, and good evidence of long-term maintenance of restored circulation. Precise and accurate localization of the lesion is probably the most important factor in proper selection of patients for operation. While certain tests may be of indicative value in this regard, in the final analysis angiography is absolutely essential for this purpose.⁶²⁻⁶⁴ For this reason recent developments providing safer and improved methods of coronary arteriography are most encouraging.⁶⁵⁻⁷¹ Ready application of coronary arteriography will not only be of great value in the preoperative selection of patients for operation but will also provide more precise and accurate evaluation of the operative procedure by subsequent visualization of the coronary arterial tree. Progressive developments along these lines and increasing experience gained with application of these surgical procedures in segmental occlusive lesions in other small arteries should permit further refinements in technic and improvements in surgical management which would lower the operative risk to acceptable levels. There are sufficiently encouraging reasons to believe, therefore, that more intensive investigations of this approach toward relief of coronary occlusive disease are fully justified.

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